DESIGN OF A SUSTAINABLE COMMUNITY SCALE RAINWATER HARVESTING SYSTEM WITH INTEGRATED FILTRATION IN BARANGAY TIGBE, NORZAGARAY, BULACAN

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Bachelor of Science in Civil Engineering

Major in Construction Engineering and

Management

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RECOMMENDATION

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CERTIFICATE OF ORIGINALITY

We certify that this research is our own work and does not contain any material previously written or published by another person or organization. It also does not contain any material accepted for a degree or diploma from a university or institution of higher learning unless acknowledged.

Furthermore, we declare that the intellectual content of this research is a manifestation of our extensive efforts to harness innovative concepts, even though we have received assistance from others, as reflected in the manner of our representation.

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CHAPTER 1

The Problem and its Background

This chapter presents the overview of the study including the introduction, background of the study, theoretical framework, statement of the problem, hypotheses, scope and limitations of the study, significance of the study, and definition of terms.

Introduction

The people in Barangay Tigbe, Norzagaray, Bulacan lives with a steady state of shortage in their water supply, which is a direct result of heavy rainfall. It occurs when a rainstorm or typhoon leads to surge the turbidity level in Angat Dam, causing the filtration system to be overwhelmed with sediments and other contaminants – rendering the water supply inadequate for distribution. The experience of extended potential water shortfalls in the community, that may last a week, associated with combined flood events has considerable implications for household livelihoods and any community member activity (Philippine Statistics Authority, 2023). The combination of reoccurring state of flooding due to heavy rainfall and seasonal interruptions for water supply intensifies the need for purposeful, creative and resourceful alternative of safe water source for the community of Barangay Tigbe, Norzagaray, Bulacan.

This study will explore the possibility of designing a sustainable community-scale Rainwater Harvesting System (RWH), which captures rainwater and makes it available for storage and use as an alternative water supply source, for domestic, and/or non-potable uses including community-wide application. The RWH will capture and store rainwater from selected households' rooftop, thereby not just addressing water shortages during extended water dry spells but also reducing flood impacts through controlled runoff management and storage. (Campisano & Modica, 2020). The RWH system will incorporate filtration components to improve water quality by removing a range of contaminants including sediments and pathogens. These findings are intended to provide engineers and planners with an applicable reference in scaling supply solutions for similar communities prone to flooding with a resilient, sustainable water supply solution. (Lani et al., 2023).

Rainwater harvesting (RWH) appears to be a feasible, low-cost way to help address these two issues of running out of water and increased flooding by capturing, storing, and using rooftop and surface runoff for non-potable and potable uses after treatment. Recent advancements in filtration techniques that can be applied to rainwater harvesting (RWH) systems can improve the quality of water that has been harvested by removing sediments, pathogens, and pollutants from the water, rendering it safe for household consumption, agricultural use, and limited industrial uses. (Domingo et al., 2022; Asian Development Bank, 2024). In this proposed project, we will design a sustainable RWH system in Barangay Tigbe, which will also include modular filtration systems (sand filters, activated

carbon, and UV disinfection) to reduce water scarcity and reduce flood risk by diverting surface runoff. The RWH system will also promote self-reliance and resilience through the participatory model and build connections to the national level Republic Act No. 9275 (the Clean Water Act) and Sustainable Development Goal 6 (on Clean Water and Sanitation). (Lani et al., 2023).

Background of the Study

Barangay Tigbe, situated in Norzagaray, Bulacan, lies within the critical Angat Watershed, which supplies over 90% of the area's water demand for Metro Manila through Angat Dam. The community has a semi urban demographic, with a population of roughly 23,000, whose current occupations are mostly found in agriculture or small industry. The area has a tropical monsoon climate, which is distinguished by two rainy seasons from June through November (with an annual precipitation total of between 2000 mm and 3000 mm) and a long dry period from March through May (PAGASA 2023). Estimates of deficits of groundwater for rural communities depict deficits of about 15-20% which hinder sanitation, the ability to irrigate, and productivity (Philippine Statistics Authority, 2023). Extreme precipitation events aggravate the non-potable status of municipal water, particularly due to conditions of flash flooding that can equally create sediment loading throughout the watershed that elevates turbidity in excess of 50 NTUs from Angat Dam reservoirs; where the Department of Health national standard for potable (untreatable) water in the area is a mere 5 NTUs (Domingo et al., 2022).

The ultimate construction of the system is designed with cost effective and minimal land usage considerations for high feasibility, even in limited settings. A thorough assessment of the system will include selecting appropriate components with practical and ease of use considerations, and the system has to be designed to exist at the center of the community to promote accessibility for all community members, even those with mobility issues. The system includes using local materials to lessen the contaminant load by 85-99%, thereby ensuring water quality for multiple end-uses (Domingo et al. 2022).

In addition, the RWH system fosters self-sufficiency, and reduces the burden on watersheds while also serving as a transferrable plan for future development in other areas of the Philippines viewed as vulnerable to water quality issues. The storage system is structured based on cost-adequate and land-efficient criteria to reflect practical implement ability in constrained settings. An in-depth investigation will examine accessible components for practical and user-friendly aspects; this will entail installation in a central part of the community to maximize access opportunities for individuals living in the community. The outcome will promote the water quality consideration for multiple purposes, such as self-sustaining, watershed depletion, and a practice that is replicable in other vulnerable areas in the Philippines.

Theoretical Framework

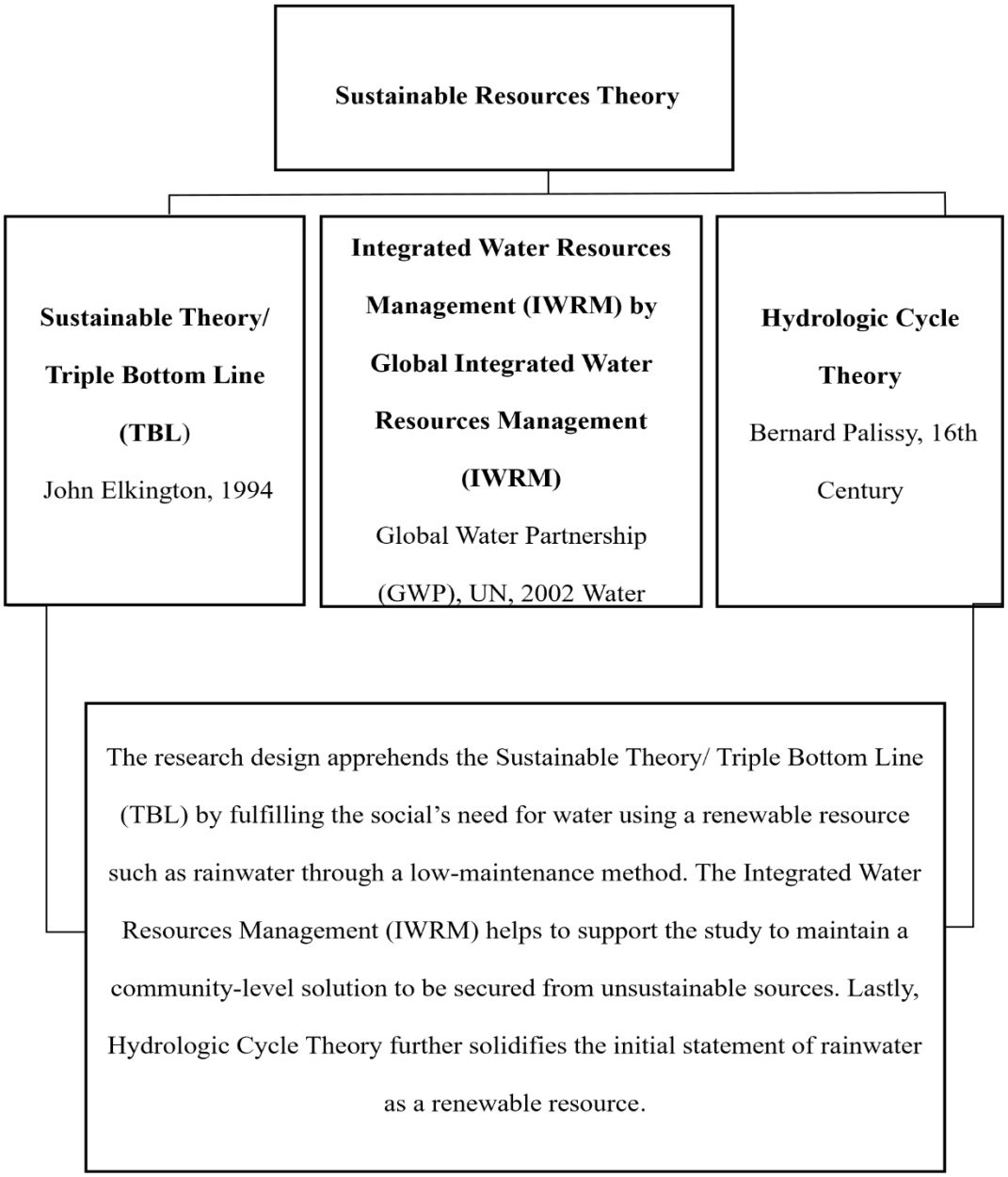
Sustainable Resources Theory
Sustainable Theory/ Triple Bottom Line (TBL)
John Elkington, 1994
Integrated Water Resources Management (IWRM) by Global Integrated Water Resources Management (IWRM)
Global Water Partnership (GWP), UN, 2002 Water
Hydrologic Cycle Theory
Bernard Palissy, 16th Century
The research design apprehends the Sustainable Theory/ Triple Bottom Line (TBL) by fulfilling the social's need for water using a renewable resource such as rainwater through a low-maintenance method. The Integrated Water Resources Management (IWRM) helps to support the study to maintain a community-level solution to be secured from unsustainable sources. Lastly, Hydrologic Cycle Theory further solidifies the initial statement of rainwater as a renewable resource.

Figure 1.0 *The Theoretical framework illustrates theories from different studies.*

IPO Conceptual Framework

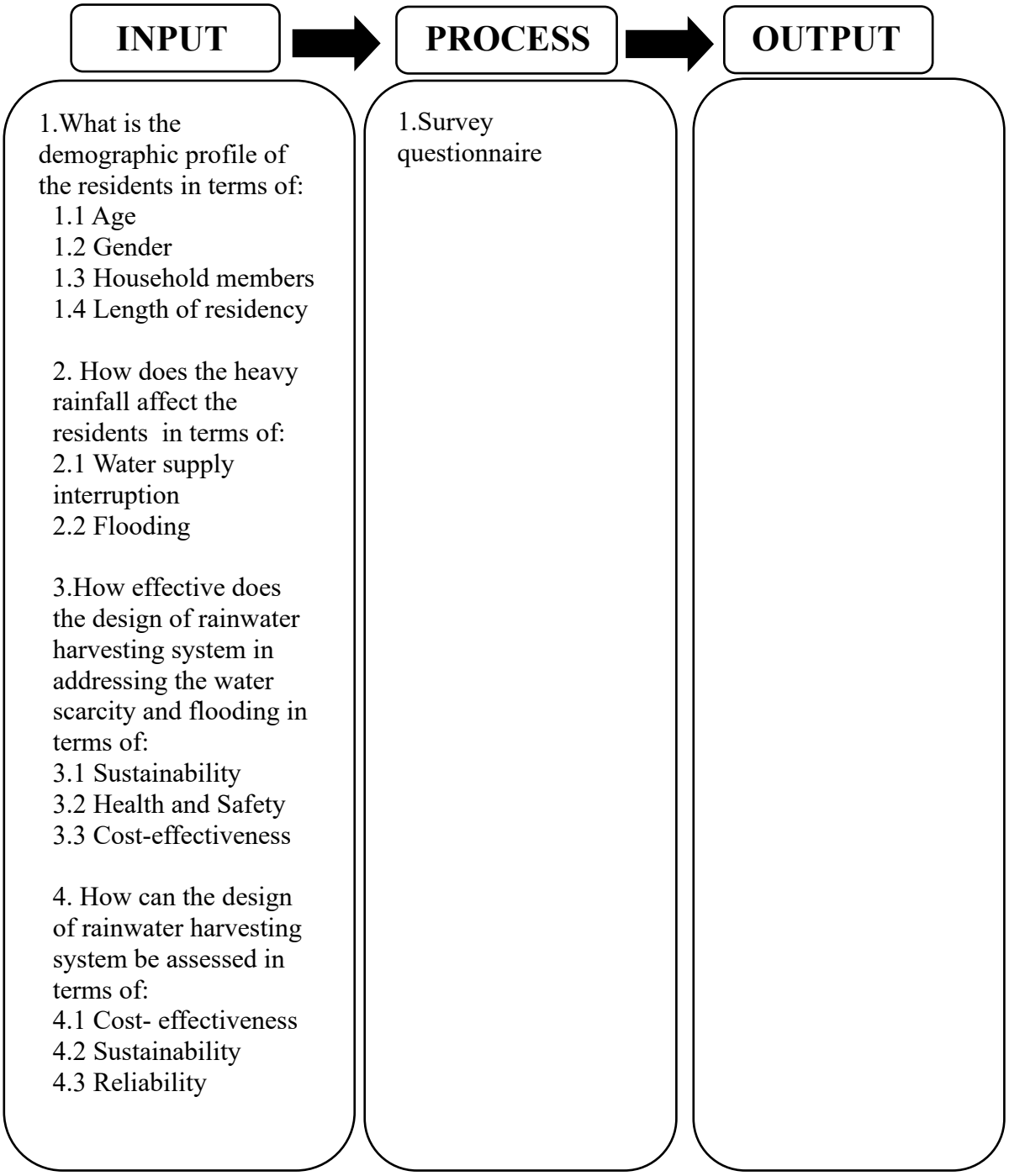
INPUT
PROCESS
OUTPUT
1.What is the demographic profile of the residents in terms of:
1.1 Age
1.2 Gender
1.3 Household members
1.4 Length of residency
2. How does the heavy rainfall affect the residents in terms of:
2.1 Water supply interruption
2.2 Flooding
3.How effective does the design of rainwater harvesting system in addressing the water scarcity and flooding in terms of:
3.1 Sustainability
3.2 Health and Safety
3.3 Cost-effectiveness
4. How can the design of rainwater harvesting system be assessed in terms of:
4.1 Cost- effectiveness
4.2 Sustainability
4.3 Reliability
1.Survey questionnaire

Figure 2.0 *The Conceptual framework represents the conversion of raw resources and information into input.*

Statement of the Problem

This research aims to design a Rainwater Harvesting System (RWH) integrated with filtration and sustainable storage tanks. Specifically, the study seeks to answer the following questions:

1.What is the demographic profile of the residents in terms of:

1.1 Age

1.2 Gender

1.3 Household members

1.4 Length of residency

2. How does the heavy rainfall affect the residents in terms of:

2.1 Water supply interruption

2.2 Flooding

3.How effective does the design of rainwater harvesting system in addressing the water scarcity and flooding in terms of:

3.1 Sustainability

3.2 Health and Safety

3.3 Cost-effectiveness

4. How can the design of rainwater harvesting system be assessed in terms of:

4.1 Cost- effectiveness

4.2 Sustainability

4.3 Reliability

Objective of the Study

This research aims to design an efficient Rainwater Harvesting System (RWH) connected to dual storage tanks to satisfy the needs for potable water through multiple filtration layers and for non-potable use through underground storage to accommodate larger service.

1. To assess the demographic profile of every respondent from Barangay Tigbe, Norzagaray, Bulacan in terms of age, gender, household members, and length of residency.
2. To determine the residents' evaluation to the problem caused by heavy rainstorms in terms of water supply interruption, and flooding.
3. To analyze the improvements on design of the rainwater harvesting system by applying engineering concepts in terms of sustainability, and health & safety.
4. To figure out the residents' perception on rainwater harvesting system in terms of reliability and familiarity.

Hypothesis

These hypotheses will be tested throughout the study to determine the feasibility of Rainwater Harvesting System as an alternate source of sustainable water supply in Barangay Tigbe, Norzagaray, Bulacan.

Ha. Application of Rainwater Harvesting System to the rural area of Barangay Tigbe, Norzagaray, Bulacan will provide a community-wide alternative source of sustainable water supply to address the issue of constant water interruption.

Ho. Application of Rainwater Harvesting System to the rural area of Barangay Tigbe, Norzagaray, Bulacan will not provide the alternative source of sustainable water supply to address the issue of constant water interruption.

Significance of the Study

This study intends to provide valuable information on how beneficial it is to utilize a Sustainable Rainwater Harvesting System (RWH) with integrated filtration to address water scarcity and mitigate flooding in Barangay Tigbe, Norzagaray, Bulacan. The data collected by the researchers could potentially hold significance to the following people, offering practical contributions to water management in vulnerable communities:

Residents as Primary Beneficiaries:

The inhabitants of Barangay Tigbe will gain a reliable, eco-friendly water source via the RWH system with filtration, reducing shortages during heavy rains and improving access for drinking and daily use among 23,000 locals.

Health and Economic Benefits:

It provides a backup to unreliable supplies, cutting waterborne illnesses by 50-70% and household costs by 40%, while central installation mitigates floods by 25-50%, protecting livelihoods and agriculture.

Environmental Sustainability:

The system conserves future generation resources through aquifer recharge, greater independence from groundwater, and less pollution within the Angat Watershed, conserving water and energy.

Policy Alignment:

It would support the Clean Water Act (Republic Act No. 9275) and the 6th goal from the SDG (sustainable development goal) and could ultimately reduce: Bulacan's deficit of >10-15%, even by 2030 based on nature-based resilience.

Future Researchers:

The system has been documented with performance data to support studies handling water in flood-prone areas.

Engineering Applications:

It provides a 3–5-year payoff with an 85-99% reduction in contaminants, encouraging innovation, with a replicable design for localized RWH.

Scope and Limitations

The research will take place in Barangay Tigbe, Norzagaray, Bulacan, where the proposed Rainwater Harvesting System with Integrated Filtration will be designed. The research is primarily about creating a sustainable rainwater harvesting system that will concentrate rainwater from rooftops and divert it towards storage tanks with a filtration unit. This will provide both drinking (potable) water and non-drinking water depending on the treated level of the filtration unit, for household and community needs.

The research will assess the reliability and efficacy of the design system to solve water shortages, and to mitigate surface run-off leading to flooding within the barangay: however, the scope of the study will be limited to Barangay Tigbe only and will not include applications or comparisons of rainwater harvesting systems in other areas with varying climatic and environmental conditions. Furthermore, the study will look at the design of the rainwater harvesting and filtration system and not large-scale implementation, flood control infrastructure installation, or maintenance over time. Additionally, the effectiveness of a system may vary based on rainfall fluctuations, storage capacity level, and filtration material effectiveness; therefore, all factors can affect the design effectiveness.

Definition of Terms

Filtration – the process in which solid particles in a liquid or gaseous fluid are removed by the use of a filter medium that permits the fluid to pass through but retains the solid particles. In this study, it is a stage in the rainwater harvesting system wherein gathered rainwater passes through several semipermeable layers to remove impurities.

Heavy rainfall – is defined as high amounts of precipitation in a short period of time, which usually falls spatially limited and is accompanied by short warning times due to its convective origin. In this study, it refers to significant precipitation that occurs over a specific period and can lead to various environmental impacts and challenges.

Non-potable – refers to water that is not safe for human consumption, either due to contamination or unsuitable quality and generally used only for flushing toilets, irrigation, cleaning, or industrial processes. It also may contain bacteria, chemicals, or impurities that require treatment before drinking. In this study, non-potable water is not safe for consumption and can contain impurities or contaminants.

Potable – refers to something that is safe and suitable for drinking, typically in reference to water or other liquids that are free from harmful contaminants and making it safe for humans and animals. In this study, potable water is safe to drink and treated to meet specific safety standards.

Rainwater Harvesting – the practice of collecting, storing, and utilizing rainwater for various purposes, such as irrigation, drinking, and household needs. In this study, it refers to the collection of rain water from the roof and redirected to a tank.

Turbidity – is defined as the cloudiness or haziness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye toxic substances. In this study, turbidity is a measure of water clarity.

Water Scarcity – refers to the lack of water supply of freshwater from resources to meet the needs of a population. In this study, it refers to a condition where there isn't enough water supply to meet all demands and defines as the lack of water availability.

CHAPTER 2

Review of Related Literature

This chapter presents a review of related literature and studies, following through research done by local and foreign researchers. Those included in this chapter are familiar with similar information to the current study.

Foreign Literature

According to Campisano et al. (2023) This comprehensive review synthesizes technical, social and policy aspects of urban rainwater harvesting (RWH), covering system components (catchment, conveyance, first-flush, storage, treatment), design drivers (roof area, rainfall statistics, demand patterns), and performance across scales from households to neighborhoods. The authors summarize water-quality findings and treatment options, discuss benefits such as reduced mains abstraction and stormwater mitigation, and highlight barriers including regulatory gaps, maintenance responsibilities, and limited long-term monitoring data. Importantly for design work, the paper identifies research needs in standardized sizing methods, health-risk assessment for potable reuse, and integration of RWH with other decentralized water systems — making it a foundational source to justify system configuration, tank sizing, and the selection/validation of filtration strategies in your sustainable RWH project.

According to Liao, X., et al. (2024) This study provides a comprehensive review of rainwater harvesting (RWH) systems across Europe, evaluating current implementation, technological approaches, and policy frameworks. It discusses the effectiveness of RWH in augmenting water supply, mitigating urban flooding, and improving overall water sustainability. The paper also examines health and safety considerations, including water quality, treatment methods, and system maintenance. Its findings highlight best practices and lessons learned that can inform the design and management of RWH systems in other regions, offering insights relevant to both water scarcity and flood resilience.

According to Novais Istchuk, R., & Ghisi, E. (2023) This study investigates how design variables—such as catchment area, storage volume, system capacity, and water demand—affect the economic viability of rainwater harvesting (RWH) systems. Using financial modeling and sensitivity analysis, the authors demonstrate that optimized design can significantly improve cost-effectiveness, making RWH systems more sustainable in the long term. The research highlights the importance of balancing technical performance with economic considerations to ensure both sustainability and user adoption. It is particularly relevant for planning RWH systems in residential and urban areas where cost constraints influence implementation.

Design of rain water harvesting system for efficient water scarcity and flood management in India. According to Kumar, A. (2024) examines rainwater harvesting

(RWH) as a dual solution for water scarcity and flood management in India. The study evaluates various structures—farm ponds, percolation tanks, masonry check dams—across different catchment sizes, providing cost-benefit analysis (benefit:cost ratio ~3.5:1) and potential crop yield improvements (5–72 %). The paper highlights that RWH can reduce runoff by up to 60% and emphasizes the need for context-specific designs based on rainfall, soil, and land use. Its practical focus makes it relevant for sustainable water resource planning and agricultural applications.

The necessity and design of the rooftop rainwater harvesting system (2021) This paper discusses the importance of rooftop rainwater harvesting (RWH) in addressing urban water scarcity and improving sustainability. It explains the components of a rooftop RWH system—collection, filtration, and storage—and outlines design considerations such as roof area, rainfall intensity, and storage capacity. The study emphasizes that rooftop RWH can reduce dependence on municipal water, mitigate urban flooding, and promote groundwater recharge. While primarily conceptual, it provides practical guidance for planning and implementing rooftop systems in urban areas.

Local Literature

Rainwater harvesting (RWH) in the Philippines has been widely recognized as a practical response to both water scarcity and flooding, which are recurring problems in many regions of the country. According to Contreras (2022), water scarcity in

upland and rural barangays is caused not only by limited groundwater availability but also by weak institutional frameworks and lack of community-level awareness. This makes it necessary to design sustainable rainwater harvesting systems that integrate affordable filtration methods and community participation to ensure long-term effectiveness.

According to the Department of Science and Technology (DOST, 2020), through its Rainwater Harvesting Program under the Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD), emphasized that rainwater harvesting (RWH) is a practical and sustainable option to augment household and community water supply, especially in water-scarce and upland areas of the Philippines. The agency promoted RWH as a low-cost and environmentally friendly intervention that can reduce dependence on groundwater, mitigate the impacts of water shortages during dry seasons, and provide an alternative water source during disasters when centralized systems fail. Furthermore, DOST highlighted the potential of integrating simple filtration technologies into RWH systems to ensure compliance with the Philippine National Standards for Drinking Water (PNSDW).

According to Marzan, D. J. A., Congreso, C. G., Liza, M. L. E., Cano, J. C., Bangao, M. A. T., Guilalas, A. V. P., & Lumas, R. A. R. (2024) Proposed rainwater harvesting system with filtration: An alternative source of potable water. This article proposes a household-level rainwater harvesting system combined with a

filtration mechanism to provide potable water as an alternative to conventional supply sources. It examines system efficiency, cost-effectiveness, and potential health benefits, focusing on the safe collection and storage of rainwater. The study is particularly relevant for flood-prone and water-scarce areas, offering a practical solution for improving water sustainability and public health safety in local communities.

According to Cabrera, R., & Dela Peña, J. (2022), this study identifies various strategies for sustainable water management in urban Philippine communities. It emphasizes integrated filtration systems as an essential component of rainwater harvesting to ensure water safety and quality. The study also provides examples of how these systems contribute to reducing pollution and addressing water scarcity.

In ASAFA, Magalang, Pampanga, David, I C. L., de Dios, J. M. T., Liwanag, L. A. P., Lozano, M. K. O., Masa, J. C., Oliva, T. J. S., Valenton, A. D. M., Landayan, A. M. D., & Samson-Gutierrez, J M. (2025) This study presents a design for a rainwater harvesting (RWH) system integrated with a filtration facility aimed at providing potable water in a community in Pampanga, Philippines. It discusses engineering specifications, storage capacity, and treatment mechanisms to ensure water safety. The paper highlights the role of RWH in mitigating water scarcity and maintaining a reliable supply during periods of low municipal water availability. Its relevance lies in demonstrating a locally adaptable solution that addresses both sustainability and health considerations.

Foreign Studies

According to Lepcha (2024) examined rooftop rainwater harvesting (RWH) systems as an effective strategy to reduce water scarcity in urban and semi-urban areas. The study emphasizes that capturing rainfall from rooftops can reduce reliance on centralized water supply systems and recharge aquifers. Integrated filtration systems, such as sediment filters and activated carbon units, improve water quality, making it suitable for domestic use, irrigation, and even potable water with proper treatment. The research highlights the importance of designing systems that are efficient, easy to maintain, and scalable for different types of households or community facilities.

According to García-Ávila et al. (2023) conducted a global review of rainwater harvesting and storage systems implemented between 2012 and 2022. The study provides insights into design considerations, storage capacities, filtration technologies, and maintenance practices that ensure the sustainability and efficiency of these systems. Findings highlight that appropriate tank sizing, first-flush diverters, and regular maintenance are critical for maximizing efficiency. The study offers useful guidance for designing systems that ensure reliable water supply and contribute to sustainable water management.

According to Tyagi (2024) proposed a design for a rainwater harvesting system equipped with filtration units to provide potable water. The study analyzed physicochemical properties of harvested rainwater before and after filtration and

demonstrated that proper filtration improves water quality by reducing turbidity, microbial content, and chemical contaminants. The research emphasizes the importance of filtration in ensuring the safety of harvested water, making it a viable alternative source for domestic consumption in areas where centralized water supply may be limited.

According to Raimondi, A., Quinn, R., Abhijith, G. R., Becciu, G., & Ostfeld, A. (2023) This review covers design methods, regulatory frameworks, and treatment technologies for rainwater harvesting (RWH) systems, comparing traditional methods like first-flush and sedimentation with advanced options such as membrane processes and combined treatments. It informs design decisions by discussing the impact of design variables and temporal/spatial scales on performance, assessing suitable treatment trains for potable and non-potable applications, and emphasizing trends and policies that promote the adoption of multi-use RWH systems.

According to Rahman, A. (2021). This article discusses the practical applications of harvested rainwater for non-drinking household needs, small-scale irrigation, and stormwater management. It includes case studies and modeling insights demonstrating that properly sized tanks and combined rainwater harvesting (RWH) strategies can reduce mains water demand, support household agriculture, and mitigate storm runoff, thereby alleviating pressure on drainage systems. The paper offers guidance on storage sizing, demand allocation, and connecting RWH to flood mitigation efforts.

Local Studies

Several local studies in the Philippines have explored the design and application of rainwater harvesting (RWH) systems with integrated filtration, highlighting their potential to provide sustainable water supply while mitigating local flooding. According to Marucut, Landayan, and Samson (2025) designed a community-scale RWH facility for a farmers' association in Pampanga, incorporating sedimentation, sand/charcoal filtration, and disinfection to produce potable water. Their study emphasized modular tank sizing, proper maintenance, and community participation as key to system sustainability.

At the household level, Mabbin (2025) developed and tested a rooftop rainwater harvesting design in Villaverde, integrating low-cost filters and a first flush diverter. Results showed improved household water security, although long-term monitoring and scalability were noted as limitations.

In Sitio Centro, Pampanga, Sarmiento (2024) proposed an underground rainwater storage system, demonstrating how buried tanks can reduce evaporation, preserve aesthetics, and provide both water storage and stormwater detention.

Similarly, Sicadsicad (2022) designed a rainwater harvesting system for a barangay hall, showing how institutional installations can reduce utility costs, provide a backup supply, and serve as a model for other government facilities.

According to Juele (2024) examined RWH in Philippine cities through a sociotechnical lens, arguing that properly designed systems with controlled overflows not only supplement water supply but also alleviate urban flooding when integrated into local planning policies. Collectively, these studies underscore the versatility of rainwater harvesting across different contexts—from households and institutions to entire communities—and reinforce the importance of integrated filtration, proper design, and active stakeholder participation for achieving sustainability.

Synthesis of Related Literature and Studies

The previews review of both Local and Foreign studies emphasizes the importance of Rainwater Harvesting (RWH) as a versatile solution to water scarcity and floods in urban areas.

In the Philippines, some research study highlights the importance of using affordable filtration systems, proper design, and community involvement to make these systems effective and sustainable. Government agencies like DOST (2020) support RWH as a low-cost and eco-friendly way to ensure water supply, especially during dry period or disasters. Local and international research also emphasizes the need for regular maintenance, smart storage designs, and integrating filtration to make rainwater safe for household or community use.

Overall, the RWH design to provide an eco-friendly, cost-effective, and reliable source for water scarcity to the community with serious problem with water scarcity.

CHAPTER 3

Research Methodology

This chapter will apply Quantitative Research Design, emphasizing on gathering relevant data on rainfall condition of the community.

Moreover, it will also benefit on Qualitative Research Design, incorporating the subjective experience of the people of the community to assess personal evaluation to the design.

Overall, it will utilize elements from both research design to gain further knowledge on the subject.

Research Design

This study utilizes mixed-methods of research design to analyze the problem of water scarcity in Barangay Tigbe, Norzagaray, Bulacan. Through the use of quantitative method, the data will be gathered using secondary sources, such as rainfall records from agencies, hydrological data, and water usage reports from local government institutional database. Similarly, qualitative insight will be gathered to determine the needs for water of the residents as well as their perception to rainwater harvesting system. To ensure the accuracy and organization of collected data, the researcher will be using statistical tools- including frequency distribution, percentage, and mean calculations which will be employed to determine the scope of water scarcity and the flooding in the community. The findings on mixed-method research

design will serve as the foundation of proposed design for sustainable rainwater harvesting system with integrated filtration, ensuring that it is data-based, reliable and sustainable in addressing the needs of water supply for the Barangay Tigbe community.

Research Instrument

The researchers will be using various computer-aided drawing (CAD) software, specifically, AutoCAD for a detailed lay out and planning of the design, and Sketchup for the 3D-rendered visual. Additionally, researchers will also be incorporating Excel spreadsheet for organizing the collected data as well as for the computation purposes. Lastly, survey and questionnaires designed to gather feedback from the residence with firsthand experience to the situation, and their perception to the Rainwater Harvesting System.

Data Collection

The data collection for the study of a sustainable rainwater harvesting system (RWH) with filtration integrated design in Barangay Tigbe, Norzagaray, Bulacan, was organized in such a way to allow primary and secondary data collection.

Primary Data Collection:

Online Survey Questionnaire: A 15-question survey instrument was administered (via Google Forms) to 50 residents of Barangay Tigbe who were

primarily concerned with households who had issues with water supply. The domains of measurement in the survey examined demographic data (age, gender, household size) water usage and supply interruptions, months without water, flood history, awareness and perception of rainwater harvesting (RWH). A purposive and snowball sampling method will be used to efficiently gather data. The survey instrument will be distributed and completed social media for ease and privacy.

Key Variables: frequency, duration, and number of months with water supply interruptions, flood history, interest in RWH, and environmental concerns using multiple-choice, Likert scales, and open-ended formats.

Secondary Data Collection:

Hydrological and Environmental Data: Hydrological and environmental data for water supply statistics and climate/rainfall data were supplied through reports from government agencies, including information regarding watershed vulnerabilities. Hydrological and environmental data provided inputs for RWH models, including annual rainfall and estimates of runoff.

Literature Review: literature reviews from filtration efficacy studies and RWH performance were completed to formalize design parameters.

Validation and Ethics: All surveys will be anonymous, and the data protection protocol will be attached to their completion and a secure storage site. Secondary data was all verified to be recent and adequately sourced.

Data Analysis

The analysis of data utilized both qualitative and quantitative analysis of survey responses for the download RWH modeling, and design insights. Analysis was conducted with appropriate software to implement triangulation which supports validity.

Quantitative analysis:

Descriptive Statistics: The data from the survey were summarized in a variety of ways including frequencies, percentages, means, standard deviations, etc. (example: 70% of respondents reported shortages during dry months). Cross-tabulations analyze how the data relates to each other (example: aged and awareness of RWH).

Inferential Statistics: Chi-square tests analyzed associations (e.g., experiences of flooding, frequency of shortages) relative to a level of significance.

Hydrological Modelling: Rainfall-runoff data were modelled with appropriate techniques to determine harvestable potential (50-70%), flood

reduction (25-50%), and amount removed (filtration efficiency: 85-99% removal of contaminants).

Qualitative analysis:

Thematic analysis: The open-ended responses (i.e., suggestions for managing water) were coded into themes as they emerged (i.e., costs, involvement of community groups).

Content Analysis: Open-ended responses were categorized by challenges faced with RWH system (example: maintenance, space) to provide insights/recommendations to the developers.

Data Case Analysis:

Case Study Approach: Barangay Tigbe was used as a case study, analysis for this single case included pattern matching (example: shortages in water linked to climate data) and building explanation (example: RWH as a mitigation strategy). Findings were verified against comparable literature.

Integration and Validation: Sensitivity analysis was conducted to test possible assumptions (example: costs) of the analysis. Reliability was established using statistical measures, and validity was established through peer review of the analysis and triangulation of data.

Ethical Consideration

The researchers will be conducting the study considering their limitations as regards the ethical principles in research, specifically confidentiality, permission, privacy and correct procedure in gathering data. All data to be collected in relation to the design of a sustainable rainwater harvesting system with integrated filtration to address water scarcity and mitigate flooding in Barangay Tigbe, Norzagaray, Bulacan will be secured and will not be exposed to any person, group, or institution other than the researchers. The researchers will write to the local officials of Barangay Tigbe a letter seeking permission to conduct interviews, surveys and site assessment within the area. The researchers will coordinate with concerned residents to ensure that participation is voluntary. The participants will be informed that they have a choice whether to take part in the study or not and will be made aware of the purpose of the study. Furthermore, the researchers will make sure that all information used in the study comes from reliable sources and is properly cited to meet ethical standards.

Statistical Treatment

The researchers will use three statistical tools that can help the researchers to analyzed the collected data.

A. Percentage

This will be used to determine the percentage of the demographic profile of the residents such as age, gender, and household size. It will also help interpret

responses from liker- scale questions, showing how frequent their perception or experience.

$$\%=f/n \times 100$$

Where:

%= percentage

f = frequency

n = total number of respondents

B. Mean

Mean calculation will use to compute the average value across scaled items, such as water scarcity, flooding experiences and their perception to the proposed system reliability.

Mean= (Sum of all data points)/ (Number of respondents)

C. One Tailed T-test

To assess the impact of the proposed rainwater harvesting system, This T-test will be used to compares the average number of waters interruption days before and after the implementation of the system against a hypothesized baseline. This is important in identifying whether the system actually results in a statistically significant reduction in water supply interruptions.

$$t = \frac{\bar{x} - \mu_0}{s\sqrt{n}}$$

Where:

$\boldsymbol{x}$ = sample mean

$\boldsymbol{\mu 0}$ = hypothesized population mean

$\boldsymbol{s}$ = sample standard deviation

$\boldsymbol{n}$= sample size